

CLAIMS:

1. An x-ray tube comprising at least one x-ray target substrate, wherein said x-ray target substrate comprises a molybdenum-based nanocomposite, said molybdenum-based nanocomposite comprising:

a) a metallic matrix comprising molybdenum; and

b) a plurality of nanoparticles dispersed throughout said metallic matrix, wherein said plurality of nanoparticles comprises from about 2 volume percent to about 20 volume percent of said molybdenum-based nanocomposite.

2. The x-ray tube according to Claim 1, wherein said metallic matrix comprises at least one of elemental molybdenum and a molybdenum-based alloy, and combinations thereof.

3. The x-ray tube according to Claim 1, wherein each of said plurality of nanoparticles comprises at least one of an inorganic oxide, an inorganic carbide, an inorganic nitride, an inorganic boride, an inorganic oxycarbide, an inorganic oxynitride, an inorganic silicide, an inorganic aluminide, and combinations thereof.

4. The x-ray tube according to Claim 3, wherein said inorganic oxide is one of a rare earth oxide, yttria, alumina, zirconia, hafnia, titania, calcia, magnesia, and combinations thereof.

5. The x-ray tube according to Claim 4, wherein said inorganic oxide is yttria.

6. The x-ray tube according to Claim 3, wherein said inorganic carbide is a carbide of hafnium, tantalum, molybdenum, zirconium, niobium, chromium, titanium, tungsten, and combinations thereof.

7. The x-ray tube according to Claim 1, wherein each of said plurality of nanoparticles has at least one dimension, wherein said at least one dimension is in a range from about 10 nm to about 500 nm.

8. The x-ray tube according to Claim 7, wherein said at least one dimension is in a range from about 10 nm to about 30 nm.

9. The x-ray tube according to Claim 1, wherein said plurality of nanoparticles comprises from about 4 volume percent to about 10 volume percent of said molybdenum-based nanocomposite.

10. The x-ray tube according to Claim 1, wherein said molybdenum-based nanocomposite has a strength in a range from about 400 MPa to about 1200 MPa.

12. The x-ray tube according to Claim 1, wherein said molybdenum-based nanocomposite is thermally stable up to about 2000°C.

13. The x-ray tube according to Claim 1, wherein each of said plurality of nanoparticles is substantially spherical.

14. The x-ray tube according to Claim 1, wherein each of said plurality of nanoparticles has a substantially ellipsoidal shape.

15. A nanocomposite, said nanocomposite comprising:

a) a molybdenum-based metallic matrix; and

b) a plurality of nanoparticles dispersed throughout said molybdenum-based metallic matrix, wherein said plurality of nanoparticles comprises from about 2 volume percent to about 20 volume percent of said nanocomposite.

16. The nanocomposite according to Claim 15, wherein said molybdenum-based metallic matrix comprises at least one of elemental molybdenum and a molybdenum-based alloy, and combinations thereof.

17. The nanocomposite according to Claim 15, wherein each of said plurality of nanoparticles comprises at least one of an inorganic oxide, an inorganic carbide, an inorganic nitride, an inorganic boride, an inorganic oxycarbide, an inorganic oxynitride, an inorganic silicide, an inorganic aluminide, and combinations thereof.

18. The nanocomposite according to Claim 17, wherein said inorganic oxide is one of a rare earth oxide, yttria, alumina, zirconia, hafnia, titania, calcia, magnesia, and combinations thereof.

19. The nanocomposite according to Claim 18 wherein said inorganic oxide is yttria.

20. The nanocomposite according to Claim 17, wherein said inorganic carbide is a carbide of hafnium, tantalum, molybdenum, zirconium, niobium, chromium, titanium, tungsten, and combinations thereof.

21. The nanocomposite according to Claim 15, wherein each of said plurality of nanoparticles has at least one dimension, wherein said at least one dimension is in a range from about 10 nm to about 500 nm.

22. The nanocomposite according to Claim 21, wherein said at least one dimension is in a range from about 10 nm to about 30 nm.

23. The nanocomposite according to Claim 15, wherein said plurality of nanoparticles comprises from about 4 volume percent to about 10 volume percent of said nanocomposite.

24. The nanocomposite according to Claim 15, wherein said nanocomposite has a strength in a range from about 400 MPa to about 1200 MPa.

26. The nanocomposite according to Claim 15, wherein said nanocomposite thermally stable up to about 2000°C.

27. The nanocomposite according to Claim 15, wherein each of said plurality of nanoparticles is substantially spherical.

28. The nanocomposite according to Claim 15, wherein each of said plurality of nanoparticles has a substantially ellipsoidal shape.

29. The nanocomposite according to Claim 15, wherein said nanocomposite is formed by generating a nanocomposite powder by one of mechanical milling and

cryogenic milling, consolidating said nanocomposite powder to make a green body, thermomechanically processing said green body to form said nanocomposite.

30. The nanocomposite according to Claim 29, wherein said cryogenic milling process is one of a non-reactive milling process and a reactive cryogenic milling process.

31. The nanocomposite according to Claim 29, wherein said thermomechanical processing comprises at least one of extrusion, forging, rolling, and swaging of said nanocomposite.

32. The nanocomposite according to Claim 29, wherein said nanocomposite is subjected to severe plastic deformation, where said severe plastic deformation comprises equiaxial channel angular processing of said nanocomposite.

33. The nanocomposite according to Claim 32, wherein said severe plastic deformation comprises at least one of torsion extrusion and twist extrusion of said nanocomposite.

34. The nanocomposite according to Claim 33, wherein said nanocomposite forms a portion of an x-ray target.

35. An article comprising a nanocomposite, said nanocomposite comprising:

a) a molybdenum-based metallic matrix, wherein said molybdenum-based metallic matrix comprises at least one of elemental molybdenum and a molybdenum-based alloy, and combinations thereof; and

b) a plurality of nanoparticles dispersed throughout said molybdenum-based metallic matrix, wherein said plurality of nanoparticles comprises from about 2 volume percent to about 20 volume percent of said nanocomposite, and wherein said nanocomposite is formed by providing a nanocomposite powder by one of mechanical milling and cryogenic milling, consolidating said nanocomposite powder to make a green body, thermomechanically processing said green body to form said nanocomposite.

36. The article according to Claim 35, wherein each of said plurality of nanoparticles comprises at least one of an inorganic oxide, an inorganic carbide, an inorganic nitride, an inorganic boride, an inorganic oxycarbide, an inorganic oxynitride, an inorganic silicide, an inorganic aluminide, and combinations thereof.

37. The article according to Claim 36, wherein said inorganic oxide is one of a rare earth oxide, yttria, alumina, zirconia, hafnia, titania, calcia, magnesia, and combinations thereof.

38. The article according to Claim 37, wherein said inorganic oxide is yttria.

39. The article according to Claim 36, wherein said inorganic carbide is a carbide of hafnium, tantalum, molybdenum, zirconium, niobium, chromium, titanium, tungsten, and combinations thereof.

40. The article according to Claim 35, wherein each of said plurality of nanoparticles has at least one dimension, wherein said at least one dimension that is in a range from about 10 nm to about 500 nm.

41. The article according to Claim 40, wherein said at least one dimension that is in a range from about 10 nm to about 30 nm.

42. The article according to Claim 35, wherein said plurality of said nanoparticles comprises from about 4 volume percent to about 10 volume percent of said nanocomposite.

43. The article according to Claim 35, wherein said nanocomposite has a strength in a range from about 400 MPa to about 1200 MPa.

45. The article according to Claim 35, wherein said nanocomposite thermally stable up to about 2000°C.

46. The article according to Claim 35, wherein each of said plurality of nanoparticles is substantially spherical.

47. The article according to Claim 35, wherein each of said plurality of nanoparticles has a substantially ellipsoidal shape.

48. The article according to Claim 35, wherein said thermomechanical processing is a cryogenic milling process.

49. The article according to Claim 35, wherein said cryogenic milling process is one of a non-reactive milling process and a reactive cryogenic milling process.

50. The article according to Claim 35, wherein said thermomechanical processing comprises at least one of extrusion, forging, rolling, and swaging of said nanocomposite.

51. The article according to Claim 35, wherein said severe plastic deformation comprises equiaxial channel angular processing of said nanocomposite.

52. The article according to Claim 35, wherein said severe plastic deformation comprises at least one of torsion extrusion and twist extrusion of said nanocomposite.

53. A method of making a bulk nanocomposite, wherein said bulk nanocomposite comprises a molybdenum-based metallic matrix and a plurality of nanoparticles dispersed throughout said molybdenum-based metallic matrix, and wherein the plurality of said nanoparticles comprises from about 2 volume percent to about 20 volume percent of said bulk nanocomposite, said method comprising the steps of:

a) providing a nanocomposite powder, wherein said nanocomposite powder comprises a plurality of nanoparticles and a molybdenum-based metallic matrix material;

b) consolidating said nanocomposite powder; and

c) thermomechanically processing said nanocomposite powder to form said bulk nanocomposite.

54. The method according to Claim 53, wherein said step of providing a nanocomposite powder comprises forming said plurality of nanoparticles by at least one of mechanofusion, mechanical alloying, cryomilling, and combinations thereof.

55. The method according to Claim 54, wherein said forming the plurality of nanoparticles comprises cryomilling said molybdenum-based metallic matrix material to form said plurality of nanoparticles.

56. The method according to Claim 55, wherein said cryomilling said molybdenum-based metallic matrix material comprises cryomilling said molybdenum-based metallic matrix material in a reactive atmosphere.

57. The method according to Claim 56, wherein said reactive atmosphere comprises at least one of nitrogen and a hydrocarbon.

58. The method according to Claim 53, wherein said step of consolidating said nanocomposite powder comprises pressing said nanocomposite powder to form a compact.

59. The method according to Claim 53, wherein said step of thermomechanically processing said nanocomposite powder comprises at least one of forging, hot-extruding, and hot-rolling, said nanocomposite powder.

60. The method according to Claim 53, wherein said step of thermomechanically processing said nanocomposite powder comprises subjecting said nanocomposite powder compact to severe plastic deformation.

61. The method according to Claim 60, wherein said step of subjecting said nanocomposite powder compact to severe plastic deformation comprises at least one of one of equiaxial channel angular processing of said nanocomposite powder, torsion extruding said nanocomposite powder, and twist extruding said nanocomposite powder.

62. A method of making portion of an x-ray target, said method comprising the steps of:

a) providing a nanocomposite, wherein said nanocomposite comprises a molybdenum-based metallic matrix and a plurality of nanoparticles dispersed throughout said molybdenum-based metallic matrix, and wherein the plurality of said nanoparticles comprises from about 2 volume percent to about 20 volume percent of said nanocomposite, wherein said nanocomposite is formed by providing a nanocomposite powder, wherein said nanocomposite powder comprises a plurality of nanoparticles and a molybdenum-based metallic matrix material; consolidating said nanocomposite powder; and thermomechanically processing said nanocomposite powder to form said nanocomposite; and

b) shaping said nanocomposite into a nanocomposite disk.

63. The method according to claim 62, further comprising the steps of

a) providing a substrate; and

b) bonding said nanocomposite disk to said substrate.

64. The method according to Claim 62, wherein said step of providing a nanocomposite comprises forming said plurality of nanoparticles by at least one of mechanofusion, mechanical alloying, cryomilling, and combinations thereof.

65. The method according to Claim 62, wherein said thermomechanically processing the nanocomposite powder comprises cryomilling said molybdenum-based metallic matrix material to form said plurality of nanoparticles.

66. The method according to Claim 62, wherein said cryomilling said molybdenum-based metallic matrix material comprises cryomilling said molybdenum-based metallic matrix material in a reactive atmosphere.

67. The method according to Claim 66, wherein said reactive atmosphere comprises at least one of nitrogen and a hydrocarbon.

68. The method according to Claim 62, wherein said consolidating said nanocomposite powder comprises pressing said nanocomposite powder to form a compact.

69. The method according to Claim 62, wherein said thermomechanically processing said nanocomposite powder comprises at least one of forging, hot-extruding, and hot-rolling, said nanocomposite powder.

70. The method according to Claim 62, wherein said step of thermomechanically processing said nanocomposite powder comprises subjecting said nanocomposite powder compact to severe plastic deformation.

71. The method according to Claim 70, wherein said subjecting said nanocomposite powder compact to severe plastic deformation comprises at least one of one of equiaxial channel angular processing of said nanocomposite powder, torsion extruding said nanocomposite powder, and twist extruding said nanocomposite powder.

72. The method according to Claim 63, wherein said step of bonding said nanocomposite disk to said substrate comprises one of brazing said nanocomposite disk to said substrate, diffusion bonding said nanocomposite disk to said substrate, and roll bonding said nanocomposite disk to said substrate.

73. The method according to Claim 63, wherein said step of providing a substrate comprises providing at least one of elemental molybdenum and a molybdenum-based alloy.

74. The method according to Claim 63, wherein said step of providing a substrate comprises providing a molybdenum-based matrix material.